APPLICATION OF POST MODERN PORTFOLIO THEORY TO MITIGATE RISK IN INTERNATIONAL SHIPPING

THESIS

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Abstract

United States Transportation Command (USTRANSCOM) currently uses two distinct paths to ship supply into Afghanistan. The first travels through Pakistan into Afghanistan, while the second originates in either Latvia or Georgia and finishes in Afghanistan. Currently about two thirds of the cargo moving into Afghanistan travels via the Pakistan Ground Line of Communication (PAKGLOC) while the other third travels via the Northern Distribution Network (NDN). This research uses financial concepts used for asset allocation to determine the correct amount of cargo to send down each route to minimize the risk of loss or damage while maintaining a high percentage of cargo arriving at its final destination. The concept of portfolio optimization pioneered by Dr. Harry Markowitz and still used today for investment diversification is applied to the shipping problem to minimize risk. Loss and Damage data is used from Transportation Discrepancy Reports (TDRs) and overall value is assumed to match the industry standard. Using historical data from the PAKGLOC and data synthesized from estimates of pilferage levels along the NDN, historical returns are drawn from random distributions. Using assumed levels of pilferage along the NDN of 0.25%, 0.5%, 0.75%, and 1.0%, a Monte Carlo simulation is run for 500 iterations at each level of pilferage, and a Co-Lower Partial Moment model is solved to find the optimal solution. Analysis of the data shows a wide spread of possible optimal solutions at each level of pilferage. Further investigation shows that the time correlation of the data for each route is a major factor in determining the overall optimal solution. It is found that due to the low levels of loss and damage along each route, risk is not an appropriate factor to use alone to determine the best shipping mix for cargo into Afghanistan.

To my beautiful wife and children, together we can do anything.

"If there must be trouble, let it be in my day, that my child may have peace"
Thomas Paine, "The American Crisis", 1776

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I. Introduction

General Background

As combat and nation building operations continue in Afghanistan, copious amounts of supply are needed to support the troops on the ground. The job of moving this supply into theater is a unique challenge in itself. In the earlier years of Operation Enduring Freedom, supply was moved into Afghanistan via commercial shipping lanes to Pakistan before traveling overland into Afghanistan. Beginning in 2009, however, second and third overland routes were introduced, allowing for both increased shipping capacity and risk mitigation through redundancy in the system (Kuchins and Sanderson, 2009:1). These second and third routes are known collectively as the Northern Distribution Network (NDN). The introduction of the NDN meant that US Transportation Command (USUSTRANSCOM) now had a choice as to how to ship supply: via the normal Pakistan Ground Line of Communication (PAKGLOC) or the new NDN.

Following the implementation of the NDN, a new question arose: how could USUSTRANSCOM best use this alternate distribution network to ensure supply reaches the warfighter intact and in time? The NDN could be used as a pressure release valve for the original PAKGLOC, being used only when needed; it could become a replacement for the PAKGLOC, or it could simply become another tool to shoulder the burden of moving supply safely over thousands of miles. As of 2010, the PAKGLOC still supports

about two thirds of US supply along its routes, while the NDN has taken over about one third of the load. As the NDN matures and solidifies its role in USUSTRANSCOM's toolkit, the details on its use are being constantly honed. A major question which arises is how to best use the NDN to decrease the overall risk of loss or damage in the shipping process. Reducing this risk is a stated major goal of USUSTRANSCOM regarding the use of the NDN.

A common Italian proverb warns the public not to put all of one's eggs in one basket. The lesson from the proverb, of course, is that should something happen to one basket, one would be wise to have a second basket with a few eggs held in reserve. In an extension of the metaphor, the NDN can, and does, act as a 'second basket' to ensure that supply still has a way of reaching troops in Afghanistan if something should happen to the supply line through Pakistan. The general concept behind the proverb is clear, and is the reason that for centuries systems have been built with redundancy and backup systems. The situation presented by the choice of PAKGLOC or NDN, however, provides a very clear decision between two distinct paths.

What the Italian proverb fails to tell us is how many eggs to put in each basket. While the concept of redundancy is clear, it is much more difficult to decide what the appropriate amount of a given asset should be put in a given 'basket'. How much does the overall risk decrease as each consecutive unit is placed in a secondary receptacle? At what point does that overall risk reach a minimum? How do the individual characteristics of each basket affect the system as a whole? These questions all combine in an effort to quantify the usefulness of the second basket to the system as a whole. Much like the eggs

and baskets, it is crucial to identify how to best use the NDN to decrease the overall risk in the shipping system.

As the United States continues to push forward in Operation Enduring Freedom, it is paramount that an efficient, reliable supply system exists to get crucial support materials to the warfighter. The NDN is primed to play a key role in ensuring this proper system exists. The key question that has yet to be answered, as begged by the Italian proverb, is how much supply to ship via the NDN and PAKGLOC to minimize the risk of loss and damage in transit?

Specific Background

On the first day of December 2009, President Barack Obama announced a plan to deploy 30,000 more troops to Afghanistan, almost doubling the number already in theater (Obama 2009). The addition of such a large number of troops means a proportional growth in the amount of supply needed to support the troops, and the need for a robust supply chain to ensure that the right material gets to the right place at the right time. Even before the surge was announced, a new surface route for cargo into Afghanistan was introduced into USUSTRANSCOM's toolkit to provide increased capacity and robustness throughout the supply system.

In 2008, before the introduction of the Northern Distribution Network, all cargo coming into Afghanistan would travel via sea lanes in to the Port of Karachi in Pakistan, then transfer onto trucks and moved over land into theater. After being offloaded, 66% of the cargo would head for the Torkam Gate in the city of Peshwar on the northern border of Afghanistan to complete its journey at the logistics hub at Bagram. The other

34% would head for the Chaman Gate in Baluchistan near the southern border of Afghanistan and to the logistics hub at Kandahar (Kuchins and Sanderson, 2009:5). In all, 28,000 20-foot equivalent units (TEUs) followed these routes, collectively known as the PAKGLOC, into theater in 2008 (Kuchins and Sanderson, 2009:5). A 20-foot equivalent unit (TEU) is defined as the volume of cargo that would fit into a standard shipping container with a length of 20 feet and a width of 8 feet. Most shipments will arrive in these 20 foot containers, but some will also come in 40 foot containers which are equivalent to 2 TEUs.

While 28,000 TEUs throughout the course of one year is an outstanding accomplishment on its own, there were also security concerns for supplies moving along the PAKGLOC route. Supply convoys heading into Afghanistan were stopped no less than seven times between September 2008 and March 2009 by the militant group Tehrik-e-Taliban Pakistan. The stated aims of the group, led by Baitullah Mehsud, were to stop any convoys from reaching Afghanistan, a goal which obviously was not achieved. (Kuchins and Sanderson, 2009:6). In addition, during 2008 the rate of pilferage from supply convoys ranged between 0.5 and 1 percent, an estimated $16 million loss at 1 percent. Similar rates of pilferage are currently reported along the NDN while the occurrence of pilferage along the PAKGLOC has steadily decreased. Troops in Afghanistan at the time required approximately 78 TEUs each day to sustain the mission. General Duncan McNabb, USUSTRANSCOM commander, stated at the time that “about 130-140 shipments reach Afghanistan each day (Kuchins and Sanderson, 2009:7).” While capacity was certainly diminished by stoppage, the PAKGLOC still provided the necessary capacity to support the troops on the ground.

In September of 2008, United States Central Command (USCENTCOM) approved the use of a new surface route to ship cargo into Afghanistan. This route was originally named the "Northern Ground Line of Communication." In October 2008, the name was changed to the current name, the Northern Distribution Network (Kuchins and Sanderson, 2009:8). The stated purpose of the NDN was to add redundancy to the PAKGLOC and provide the necessary infrastructure to handle the extra supplies necessary to support the 2010 troop surge (Kuchins and Sanderson, 2010:2). The NDN became operational in May 2009 using existing roadways, sea lanes, and old Soviet railways operated by contractors (Solis, 2010:6). Following the final nonlethal ground transport agreement in the summer of 2009, the fully completed NDN provides a path to Afghanistan through the Eastern European and Central Asian nations of Latvia, Azerbaijan, Georgia, Kazakhstan, Russia, Tajikistan, and Uzbekistan (Kuchins and Sanderson, 2010:1).

The Northern Distribution Network has two main points of origin, the first at the Latvian port of Riga and the second at the Georgian port of Poti. From Latvia, the first route heads south through Russia, Kazakhstan, and Uzbekistan before crossing into Afghanistan at Termez as depicted in Figure 1 below (Kuchins and Sanderson, 2009:9).

Figure 1. NDN North Route (Kuchins and Sanderson, 2009)

From Georgia, the southern route heads east through Georgia and Azerbaijan before crossing the Caspian Sea into Kazakhstan, then into Uzbekistan and finally crossing into Afghanistan at Termez as depicted in Figure 2 below (Kuchins and Sanderson, 2009:10).

Figure 2. NDN South Route (Kuchins and Sanderson, 2009)

A final spur of the NDN, referred to as the KKT Route, is a more eastward route beginning again at Riga, Latvia before heading south through Russia, Kazakhstan, Kyrgyzstan, and Tajikistan before also crossing into Afghanistan at Termez as depicted in Figure 3 (Kuchins and Sanderson, 2009:11). While these three routes describe the major structure of the NDN, it is important to remember that within each of these routes are a number of different road and rail options which make the trail a true network.

Figure 3. NDN KKT Route (Kuchins and Sanderson, 2009)

From May through November of 2009, the first six months of use for the NDN, around 4,700 TEUs were shipped into Afghanistan using the new route. In the following months, about 1,000 TEUs per month were moved along the routes (Solis, 2010:6). The new NDN provides more options for USTRANSCOM to ship cargo into Afghanistan to support OEF, but also comes with some costs. In order to ship cargo from a source of supply in the United States to its final destination in Afghanistan, one can expect a travel time of approximately 72 days via the PAKGLOC. In contrast, the same cargo moving along the NDN north or NDN south routes will take 86 or 92 days, respectively (Solis 2010:12).

The NDN was patched together using a series of nonlethal transport agreements with the nations along the path, which adds its own set of restrictions in terms of

shipping. Due to these agreements, items traveling along the NDN must be nonlethal in nature, which precludes the shipping of certain classes of supply. The Department of Defense classifies supply into ten distinct categories by the end use of the object. These classes of supply are described succinctly in Figure 4. While most classes have some items which can be sent through either route, classes such as class V supply must go exclusively through the PAKGLOC. The amount of supply eligible to travel via the NDN arriving in the first half of 2010 is displayed in

Table **1**.

	I	Subsistence items and gratuitous issue health and welfare items: MREs, T-rations, and fresh fruits and vegetables.
	II	Items of equipment, such as clothing TASO, pioneer tools, and NBC overgarments.
	III	Petroleum, oils, and lubricants.
	IV	Construction and barrier materials: lumber, sand bags, and barbed wire.
	V	Ammunition: small arms ammo, artillery, rounds, hand grenades, explosives, mines, fuzes, and detonators.
	VI	Personal demand items: post exchange system items: cigarettes, candy, and soap.
	VII	Major end items: vehicles and major weapons systems.
	VIII	Medical material: medicine, stretchers and surgical instruments.
	IX	Repair parts and components, including kits and assemblies; items for maintenance support: batteries, spark plugs, and axles.
CA	X	Material to support civil programs such as agriculture and economic development projects: commercial design tractors and farm tools.
MISC		Miscellaneous items that do not fit into one of the classes above: water, maps, captured enemy material, and salvage material.

Figure 4. Classes of Supply (Joint Publication 4-09)

Table 1. NDN Eligible Supply by Class, January through May 2010. (iSDDC)

Class	NDN Eligible
I	44.4%
II	56.5%
III	93.0%
IV	98.7%
V	0.0%
VI	100.0%
VII	54.8%
VIII	86.7%
IX	61.2%
X	100.0%

Research Problem

The problem of deciding how much supply to ship down each path is solved using a Downside Risk Optimization (DRO) framework, normally used for optimizing financial portfolios. When assembling financial portfolios, planners advise clients to "diversify." The major component at work behind diversification of investments is the correlation between two given investments. If one were to consider investing in a number of companies which manufacture the same product, it can be assumed that if the stock of one of those companies were to rise or fall, the stock of the others would probably follow the same general trend. In this case, there is a high correlation between the stocks and they behave in a similar manner, leaving the investor with no choice but to accept the risk involved in the investment. If that same investor were to invest in one manufacturing company and one company providing an unrelated service, however, the investor can assume that just because the manufacturing company's stock decreases, the service company's stock will probably hold its value. Downside Risk Optimization is a model

used to minimize risk in a given financial portfolio for a given minimum acceptable return.

In the case of USTRANSCOM's shipping problem, a similar dynamic is at work. Because the NDN and PAKGLOC are in different places, there is a fairly small degree of correlation between the two. Given this difference, the shipper uses the same diversification technique as the investor above, essentially diversifying between the two shipping routes and thereby avoiding some risk for the same expected level of return. When the financial DRO model is applied to the shipping world, some of the figures will change. The expected return on an investment, for example, will translate to the value of a shipment reaching its final destination minus any loss or damage along the path. These figures will be adjusted as necessary to ensure the model provides valid results.

Methodology

This research effort produces a set of guidelines for the percentage of supply to be sent down each route in order to minimize risk. The first step is to build the delivery percentages for each path. The values for loss and damage are taken from Transportation Discrepancy Reports filed with USTRANSCOM for shipments along the PAKGLOC and NDN, along with estimates of pilferage where appropriate. Full values for shipments along the PAKGLOC are found based on average values for shipments by class of supply, and the values for the NDN are extrapolated based on estimates of pilferage and small losses along the path.

Following the building of percentages, the return and risk values are found along with shipping costs for the current shipments along the NDN and PAKGLOC to find a

baseline set of values against which future mixes are compared. These historical risk and return values are then analyzed using a downside risk optimization framework to find the mix of routes for each class which minimizes risk while still meeting a minimum acceptable return. A third objective, shipping cost, is be considered both as a source of optimization in place of downside risk, and as a constraint along with risk and return to find a budget friendly route mixture for future shipping.

Scope and Limitations

The purpose of this research is to create a set of guidelines for how much cargo should be shipped into Afghanistan using the NDN and how much to ship using the PAKGLOC. The final product must be concise, clearly understandable, and available for update at points in the future. While cargo flowing into Afghanistan comes from all around the world, the point of origin is not considered, nor is the individual carrier. In addition, there are a number of distinct routes along both the NDN and PAKGLOC; however, this research focuses on the two routes as a whole as specific data on each route is not currently available. This research is very general in the sense of the NDN and PAKGLOC in order to provide a useful guideline for USTRANSCOM planners in the near future.

Review of Chapters

Chapter 2 consists of a literature review, focusing heavily on the development of downside risk optimization into what is currently referred to as "Post-Modern Portfolio Theory." It begins with the foundations of portfolio optimization as created by Harry

Markowitz in 1952 and includes discussion to the present day on the subject. The purpose of the literature review is to depict the development of the specific model used in this research from its genesis. Chapter 3 discusses the development of the downside risk optimization model as it specifically applies to the international shipping program, especially discussing the adjustments made to account for the unique situation which shipping presents. Chapter 4 documents the results of the optimization routine for each case, including the specific percentage of cargo which should be shipped along each route. Finally, Chapter 5 summarizes the results of the research and presents the final product: a set of specific guidelines for the percentage of cargo to ship along the NDN and PAKGLOC

II. Literature Review

Harry Markowitz: The Father of Modern Portfolio Theory

In 1952, Dr. Harry M. Markowitz of the RAND Corporation published a concise article in *The Journal of Finance*, entitled "Portfolio Selection." Markowitz's work was the first published guide to the shrewd investor on how to appropriately diversify one's investments using sound mathematical concepts. This paper, along with some of Markowitz's other works, sparked a new area of economic research collectively known as "Modern Portfolio Theory," and is still considered to be one of the foundations of economic theory, garnering Markowitz a share in the 1990 Nobel Prize for Economics.

Markowitz's work first attempts to define a general rule of investor behavior. The paper dismisses the idea that the rational investor attempts simply to maximize the expected return of his or her portfolio as being far too exclusive. Given this rule, an investor would simply aim to find the best performing investment and put all of his or her resources into that commodity, suggesting that there is no diversified portfolio which would outperform an undiversified portfolio (Markowitz 1952:77). While diversification had not been subject to distinct mathematical analysis in the past, it had been accepted as a general investing strategy which provided greater success to investors. Markowitz puts forth instead that an investor "does (or should) consider expected return a desirable thing *and* variance of return an undesirable thing (Markowitz 1952:77)."

The work goes on to define both expected return and variance of return of the portfolio as simple mathematical concepts. The expected return of the portfolio is simply a weighted sum of the returns of the individual securities in the portfolio, defined as:

$$E = \sum_{i=1}^{N} X_i \mu_i \qquad (2.1)$$

Where E is the expected return of the portfolio; N is the number of assets in the portfolio; X_i is the percentage of the portfolio allocated to asset i; and μ_i is the expected return of asset i (Markowitz 1952:81). After some development of the variance of a weighted sum, the variance of the portfolio is then given as:

$$V = \sum_{i=1}^{N} \sum_{j=1}^{N} \sigma_{ij} X_i X_j \qquad (2.1)$$

Where V is the total variance of the portfolio; X_i and X_j are the percentages of the portfolio allocated to assets i and j, respectively; and σ_{ij} is the covariance of the returns of assets i and j (Markowitz 1952:81). The covariance term is further defined as:

$$\sigma_{ij} = \rho_{ij} \sigma_i \sigma_j \qquad (2.2)$$

Where σ_{ij} is the covariance of the returns of assets i and j, ρ_{ij} is the correlation coefficient between the two assets i and j, and σ_i and σ_j are the variances of assets i and j, respectively (Markowitz 1952:80).

Using the variables defined above, Markowitz uses the weighted sum of expected returns of each asset in the portfolio as the expected return on the entire portfolio, and uses the variance of the portfolio as a measure of the overall "risk" of the portfolio. He also provides a general relationship between the expected return and expected variance of an asset, stating: "The portfolio with maximum expected return is not necessarily the one with minimum variance. There is a rate at which the investor can gain expected return by taking on variance, or reduce variance by giving up expected return (Markowitz 1952:78). Given this inverse relationship which exists, at least anecdotally, for financial

assets, Markowitz puts forth the notion that there is an efficient set of portfolios which give a minimum risk level for a given return, and a maximum return for a given risk level (Markowitz 1952:82). Figure 5 below, where the y-axis shows portfolio variance and the x-axis shows portfolio return, shows a region of possible risk and return combinations given a set of assets from which to compile a portfolio.

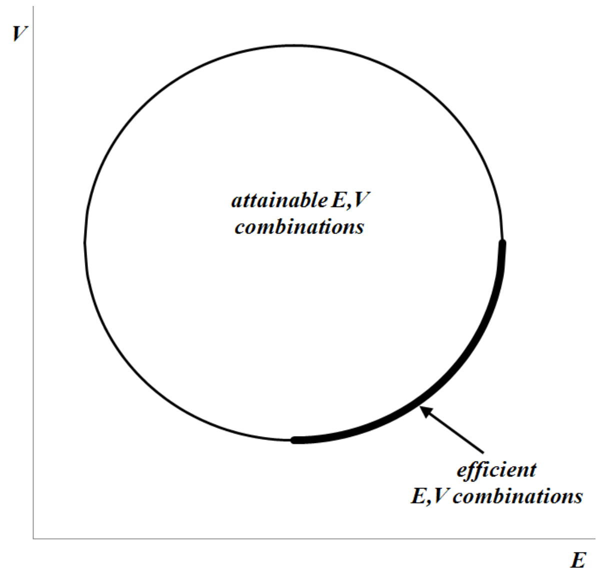


Figure 5. Risk and Return Combinations (Markowitz 1952:82)

The bold line in Figure 5 represents the set of risk and return combinations which are defined as efficient, meaning that one cannot increase the expected return on the portfolio without also increasing risk, and conversely one cannot decrease the risk of a portfolio without also decreasing the expected return (Markowitz 1952:82). This set is the group of portfolios in which the shrewd investor should be interested. The final mathematical optimization model which is indicated by Markowitz's research is:

$$
\begin{aligned}
&max \ \sum_{i=1}^{N} X_i \mu_i \\
&min \ \sum_{i=1}^{N} \sum_{j=1}^{N} \sigma_{ij} X_i X_j \\
&Subject \ to \\
&\sum_{i=1}^{N} X_i = 1
\end{aligned}
\tag{2.3}
$$

This optimization can then be implemented using any number of multi criteria optimization techniques to arrive at the appropriate efficient portfolio for a given investor. Markowitz concludes his article by reminding the investor that diversification is the key: "Suppose an investor diversifies between two portfolios… If the two original portfolios have *equal* variance then typically the variance of the resulting (compound) portfolio will be less than the variance of either original portfolio" (Markowitz 1952:89).

Treynor and Sharpe: Creating a Single Performance Metric

In 1965, Operations Research Analyst Jack L. Treynor published an article in the *Harvard Business Review* in which he set out to define a way to rate the management of investment funds. In a market defined by risk and return, there was not yet a single utility function which could capture both dimensions of a portfolio's performance. Treynor uses a set of indifference curves on a graph of risk and return as a framework for the development of his measure, citing their popularity among investors and mutual fund managers (Treynor 1965:67). The indifference curves used on the charts are defined as points on the risk-return graph where the investor would be indifferent to portfolio choices along the curve. Put more simply, the investor would see the amount of risk taken on and the amount of expected return to be gained as equal along these curves

(Treynor 1965:68). These indifference curves vary significantly between investors and situations and their calculation is outside the scope of this work. Treynor's work, however, goes on to show that the specific curves are not important, and that a general case serves the required purpose (Treynor 1965:68).

The method presented first requires the funds to be considered to be graphed along with the indifference curves, as shown in Figure 6, according to their individual expected return and risk, defined as the standard deviation of the returns for a fund. Following the plotting of these funds, a straight line is drawn between the point of the fund and the point of a risk free asset, generally considered to be a treasury bond or the like (Treynor 1965:68). Treynor then posits that the combination which is best for the investor will lie at the point where the line between a fund and the risk free asset is tangent to any given indifference curve. This tangential relationship indicates that the acceptable tradeoff for the investor has been reached, and that the given portfolio has the best risk to return relationship (Treynor 1965:69). Further, given a risk-averse investor, it can be seen that the slope of the line between a fund and the risk-free asset is directly proportional to the desirability of the fund (Treynor 1965:69). In the example provided by Figure 6, the point representing Fund A would be preferable to the point representing Fund C for the risk-averse investor due to a more preferable relationship between risk and return.

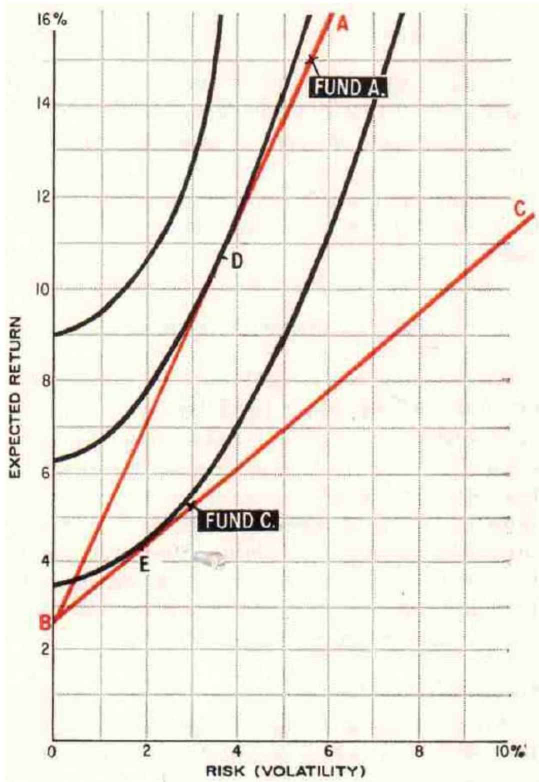


Figure 6. Risk and Return Indifference Curves (Treynor 1965:68)

Given the relationship between the slope of the line and the desirability of a fund, a quantitative measure can be derived. The slope of the line between a fund and the risk-free asset can be described by:

$$\alpha = \frac{\mu - \mu^*}{\sigma - \sigma^*} \tag{2.4}$$

Where α is the slope of the line; μ and σ are the expected return and risk of the fund in question, respectively; and μ^* and σ^* are the expected return and risk of the reference fund (Treynor 1965:69). In the case presented by Treynor, the reference fund is a risk-free asset, so the equation reduces to:

$$\alpha = \frac{\mu - \mu^*}{\sigma} \tag{2.5}$$

The measure α provides a single number which represents the amount of return for each unit of risk undertaken. Given Markowitz's investing maxim that expected returns are desirable and risk is undesirable, the logical investor would seek to build a portfolio with the greatest possible value of α. Even to novice investors, this measure seems sound given its resemblance to other common ratios of desirable measures to undesirable measures to include thrust to weight ratio in an aircraft or even the popular cliché "bang for your buck." It is important at this juncture to note that the values in Treynor's work are reasonable predictors of future performance in terms of risk and return.

One year after the publishing of Treynor's findings, Economist and 1990 Nobel Prize winner (alongside Dr. Harry Markowitz) Dr. William F. Sharpe followed up with a study providing empirical proof of Treynor's ratio and applying the same concepts to the field of portfolio analysis and asset allocation. Sharpe begins a discussion of portfolio analysis theory by clearly laying out the duties of the portfolio analyst, the security analyst, and the investor. The duties of the portfolio analyst, in the case of the current research the author, are to translate predictions about security performance into predictions about portfolio performance, and to select from an infinite number of portfolios those which are efficient, as defined by Markowitz (Sharpe 1966:120). The security analyst, in our case USTRANSCOM, has the duty of providing appropriate predictions of security performance; and finally the investor, also USTRANSCOM, must

select his or her most desirable portfolio from among those considered to be efficient (Sharpe 1966:120).

Sharpe restates Treynor's quantitative measure with a slight modification:

$$E = p + \left(\frac{E_i - p}{\sigma_i} \right) \sigma \tag{2.6}$$

Where E is the overall expected return of the portfolio; p is the expected return of the risk-free asset; E_i and σ_i are the expected return and risk of asset i; and σ is the risk of the entire portfolio (Sharpe 1965:122). This equation is simply that of the entire line as drawn on the indifference curves instead of only the slope, and represents the full set of efficient portfolios consisting of a single fund and a risk-free asset.

The main purpose of Sharpe's work is to show the validity of using ex post values as predictors of ex ante values (Sharpe 1965:122). Indeed, many works regarding the prediction of future performance of funds or portfolios have stated a similar disclaimer that while past values may not be perfect, they are a good baseline indicator of future performance. Markowitz himself stated: "[The procedures for finding reasonable expected returns and expected risk] should combine statistical techniques and the judgment of practical men" (Markowitz 1952:91). This concise statement captures the intent of Sharpe's work, yet still allows some modification based on the judgment of the analyst.

Sharpe goes on to create a modified ratio where measures of past performance are substituted as predictors of future performance.

$$A = p + \left[\frac{A_i - p}{V_i} \right] V \tag{2.7}$$

Where A is the average rate of return for the portfolio; p is, again, the expected return of the risk-free asset; A_i and V_i are the average rate of return and the standard deviation of the rate of return, respectively; and V is the overall standard deviation of the returns for the portfolio (Sharpe 1966:123). By extraction, we can see the adjustment to Treynor's measure to include past values becomes:

$$\hat{\alpha} = \left[\frac{A_i - p}{V_i} \right] \tag{2.8}$$

Sharpe calls this ratio the reward-to-variability ratio (R/V), but over time it has become known as the Sharpe Ratio, and is still a popular measure of portfolio performance (Sharpe 1966:123). Using values for return and variability of 17 funds from 1944-1953 and from 1954-1963, Sharpe goes on to show that if one were holding one of the seventeen best funds in the first decade, one would have about a 65% chance of holding one of the seventeen best funds in the second decade (Sharpe 1966:127). Finally, the work compares the predicted performance of the funds from 1954-1963 as calculated using the Treynor Index to the actual performance of the fund using the reward-to-variability ratio, and finds a correlation of approximately 0.454, a highly significant correlation (Sharpe 1966:129).

Bawa and Harlow: Semivariance as a Measure of Risk

In 1959, Dr. Harry Markowitz expanded upon his discussion of portfolio selection and published a full book on the subject. In this 1959 work, Markowitz devoted an entire chapter to a measure called "semi-variance" in which he derives and applies the measure, then states: "Variance is superior with respect to cost, convenience, and familiarity"

(Markowitz 1959:193). In 1959, the difference in computing time between the variance and semivariance would have been quite substantial. Over time, however, that time difference has become much smaller, even negligible. Even though it was not used in his original theory, Dr. Markowitz led the way with the suggestion of a downside risk measure.

Semivariance is defined as:

$$\frac{\sum_{r_i<\mu}^{n}(\mu - r_i)^2}{n} \tag{2.9}$$

Where r_i is the ith return of asset r; n is the total number of returns; and μ is the average of the returns (Markowitz 1959:189). This summation is immediately familiar due to its similarity to the general formula for variance, but with a slight change. While the formula still consists of the expected value of the squared difference between returns and the mean, the summation only takes into account those returns which fall below the mean, providing a measure of the lower half of the variance. Put another way, this measure is the average variance of the returns under the mean. The semivariance is immediately an attractive measure of risk as compared to variance due to its similarity to the psychology of investors in the sense that variance below the expected return is undesirable, while variance above the expected return is desirable or neutral (Harlow and Rao 1989:285).

While semivariance itself is an intuitively appropriate measure, it was expanded upon a number of times and transformed into a lower partial moment formula which provided more generality in terms of the application of the function (Sing and Ong

2000:215). A paper by Dr. Vijay Sharma in 1975 defined the lower partial variance of a continuous distribution as:

$$LPV_f(x) \equiv \int_a^x (y-x)^2 \, dF(y) \tag{2.10}$$

Where *a* is the left hand side of the distribution; *x* is the expected return on the portfolio; *y* is the return at point *y*, and *dF(y)* is the distribution of the returns (Bawa 1975:110). Bawa then goes on to discuss the possibility of using other moments instead of using only the second moment, which is simply the continuous case of the semivariance measure (Bawa 1975:111). For generality, the definition of lower partial moment was expanded in 1976 to be:

$$LPM_n(x;F) \equiv \int_a^x (y-x)^n \, dF(y) \tag{2.11}$$

This definition is nearly identical to the definition in equation (2.10) with the substitution of a parameter *n* so that the formula may be used for any moment of the distribution (Bawa 1978:258). In 1977, the formula was expanded into a full portfolio optimization model:

$$\begin{aligned} &for \;\; n = 1,2: \\ &\min_x \; LPM_n(r_F; X) \\ &subject \;\, to \; \sum X_i E_i = \mu \end{aligned} \tag{2.12}$$

Where r_F is the return on asset *r*, *X* is the probability distribution of the portfolio, X_i is the percentage of the portfolio allocated to asset *i*; E_i is the expected return of asset *i*; and μ is the expected rate of return for the portfolio (Bawa 1977:193). This model will minimize the lower partial moment of the portfolio as a means of minimizing downside

risk while requiring that the weighted sum of returns is equal to the expected return on the entire portfolio. Put more simply, this model minimizes the downside risk of the portfolio for a given rate of return.

In 1989 Dr. W. V. Harlow and Dr. Ramesh K. S. Rao published a paper which served two major purposes: to introduce the idea that the target rate of return could be any value given by the investor instead of only the expected return, and to provide empirical testing of the LPM (Lower Partial Moment) model which uses a measure of semivariance on the downside of the curve to depict risk. Harlow and Rao recognized that the LPM model had been neglected for some time because empirical studies in 1976 and 1981 showed that the LPM model did not provide a substantial improvement over the mean variance optimization model (Harlow and Rao, 1989:286). They set out to modify the existing LPM model to include any target rate specified, hypothesizing that this change in thinking would provide some new substantive results.

Harlow and Rao modified the objective of the LPM model as such:

$$LPM_n(\tau, X) = \int_{-\infty}^{\tau} (\tau - R_x)^n dF_X(R_X) \tag{2.13}$$

Where τ is defined as an investor's minimum acceptable return, R_X is the return on the portfolio, and F_X is the probability distribution of returns on the portfolio (Harlow and Rao 1989:290). Harlow and Rao suggest that the formula be used with $n = 2$ when dealing with the average investor who is risk-averse and has a preference for skewness (Harlow and Rao 1989:306). The authors continue by analyzing data from 1931 through 1980 to attempt to find a statistically significant difference between the results of their

model and the results of the mean variance model, and were successful in doing so at a 95% confidence level.

The development of a lower partial moment model solved two critical problems which dominate the mean variance optimization method. First, where the mean variance optimization method required returns to follow a bell shaped curve, the lower partial moment will more properly analyze skewed distributions which are more likely to occur (Harlow 1989:287). Second, the lower partial moment provided a more intuitive measure of risk as the portion of the variance of returns which falls below the target rate of return, allowing the investor to make decisions based on the possibility of not meeting the target rate instead of simply minimizing variance on both sides of the target (Sing and Ong 2000:215).

Sortino and Lee: A Performance Measure for Downside Risk Optimization

With the emergence of the downside risk optimization framework, investors had a mathematical model that was more intuitive and flexible in terms of describing the investor's attitude toward risk. As with Markowitz's mean-variance optimization, however, analysts were left with a multi-criteria optimization problem to be solved using any generic method. Recall the Sharpe Ratio for mean-variance optimization (2.7):

$$\hat{\alpha} = \left[\frac{A_i - p}{V_i} \right]$$

Downside risk optimization requires the replacement of two variables in the Sharpe Ratio. First, LPM models no longer use the average return of the asset as a target

point, but instead allow the investor to name his or her own minimal acceptable return. In addition, the variance of the asset is no longer an appropriate measure due to the complete restructuring of the risk measure. In 1994, Dr. Frank Sortino and Dr. Lee Price set out to update the Sharpe Ratio for use with downside risk optimization models. In 1994, about 75% of investment analysts who where familiar with downside risk considered it to be a better measure of performance than mean-variance optimization (Sortino and Lee 1994: 4). Sortino and Lee first make the simple substitution of replacing expected return in the Sharpe model with a minimum acceptable return in the new Sortino Ratio (Sortino and Lee 1994:4). Sortino and Lee also take the step of comparing the LPM measures of Bawa and Harlow to the variance used by Markowitz in terms of their meaning. In the Sharpe model, the denominator is the familiar standard deviation of the returns. Sortino and Lee suggest using the standard deviation of the downside risk for the denominator of the ratio, which equates simply to the square root of the LPM value (Sortino and Lee 1994:4). The final Sortino Ratio, therefore, is:

$$\widehat{\alpha} = \frac{\mu - \tau}{\sqrt{LPM_n(\tau, X)}} \tag{2.14}$$

Where μ is the expected return on the portfolio, τ is the minimum acceptable return of the investor, and the LPM measure is generated from equation (2.13).

Sing and Ong: An Inclusive Optimization Model

In 1977, Bawa and Lindbergh introduced a version of the LPM model which went mostly unnoticed in subsequent literature. The measure recognized the lack of inclusion

of correlation between assets in other LPM models and set out to create a combined model. After some mathematical development, the co-lower partial moment (CLPM) is presented as:

$$CLPM_n(\tau; i, j) = \int_{r_i=-\infty}^{\tau} \int_{r_j=-\infty}^{\infty} (\tau - r_i)^{n-1}(\tau - r_j) dF(r_i, r_j) \tag{2.15}$$

Where τ is the minimum acceptable return as defined by the investor; r_i and r_j are the returns of assets *i* and *j*, respectively; and *dF* is the joint probability distribution of assets *i* and *j* (Bawa and Lindbergh 1977:197). This model incorporates both the downside risk concept of traditional LPM models and the correlation of the two assets, put forth as a crucial concept by Markowitz. The major drawback of this model is the computational complexity, especially when compared to the original Markowitz model consisting of only mean and variance measures.

In a 2000 article in the *Journal of Real Estate Portfolio Management*, Dr. Tien Foo Sing and Dr. Seow Eng Ong of the National University of Singapore provide analysts with a way of mitigating the computational complexity of the CLPM measure such that the analysis may be done in a simple spreadsheet (Sing and Ong 2000:214). Sing and Ong provide a discrete form of the CLPM measure:

$$CLPM_n(\tau, R_i, R_j) = \frac{1}{T-1} \sum_{t=1}^{T} [Max(0, (\tau - R_{it}))]^{n-1}(\tau - R_{jt}) \tag{2.16}$$

Where τ is the minimum acceptable return of the investor; *T* is the number of observations; and R_{it} and R_{jt} are the returns on assets *i* and *j*, respectively, at time *t* (Sing and Ong 2000:215). This formula provides an individual with a method of finding the

co-lower partial moment of two assets using only a minimum acceptable return and a list of returns for each asset, greatly reducing the computational complexity of the problem. The authors go on to provide a final optimization model using the CLPM measure:

$$\begin{aligned}
&Minimize\ G(x) = \sum_{i=1}^{N}\sum_{j=1}^{N} x_i x_j CLPM_n(\tau, R_i, R_j) \\
&Subject\ to \\
&\sum_{i=1}^{N} x_i \bar{R}_i \geq \tau \\
&\sum_{i=1}^{n} x_i = 1 \\
&x_i \geq 0, \quad i = 1, 2, \ldots, N
\end{aligned} \tag{2.17}$$

Where x_i and x_j are the percentages of the portfolio invested in assets *i* and *j*, respectively; τ is the minimum acceptable return of the investor; and $\bar{R}_i$ is the average return of asset *i* (Sing and Ong 2000:217). This model allows the investor to set a level of return they would like to attain, then reduces the portion of the variance of returns which falls below that given level of return through diversification. In short, this model provides us with the crucial information the research has been searching for: how many eggs to put in each basket.

III. Methodology

Model Adaptation

As discussed in Chapter 2, the Sing and Ong CLPM model combines the concepts of expected returns, covariance, downside risk, and an investor-defined minimum acceptable return into a single, spreadsheet-capable model. Given the benefits offered by this model, it is a natural choice for the analysis of the optimal routing problem. The problem of shipping cargo internationally, however, differs appreciably from a stock investment problem, and the CLPM model, therefore, requires some level of adaptation to make it appropriate to solve the problem at hand. There are three major parts to the CLPM model: expected returns, downside risk, and an investor-defined minimum acceptable return.

Expected Returns

Returns for a stock investment problem generally follow a skewed, bell-shaped curve and are not bounded on either end of the distribution. The distribution of returns for a shipping problem, however, intuitively differs in a number of ways. The returns for the shipping problem are represented by a simple ratio of the value of cargo reaching its final destination to the value of cargo that left the port of origin; in essence these returns are the percentage of cargo reaching its final destination. Given this assumption, it is clear that the simple magnitude of values to be considered differ greatly. Instead of a stock or mutual fund with a 10% return, the shipping problem instead deals with values such as a 99% or even 100% arrival percentage. In addition, a stock or mutual fund can have returns with any value because of the unbounded nature of the distribution of

returns. It is impossible, however, for the percentage of cargo value arriving at a final destination to be above 100% or below 0%. Also, the general shape of the distribution has the possibility of varying widely for the shipping problem. Instead of a simple two-parameter bell-shaped curve, it is possible that the percentage of cargo value arriving at a port could follow a more complicated lognormal distribution, or a discretely bounded triangular distribution. Should the shipping returns follow a complicated or bounded distribution, some standardization may need to occur before the data is analyzed.

Covariance and Downside Risk

The concepts of covariance and downside risk for the distribution of shipping returns are calculated the same way as with financial returns. Thanks to the LPM (Lower Partial Moment) concept, there are no changes necessary to calculate downside risk for distributions which are not bell-shaped. In addition, the CLPM model assumes a skewed, non-normal distribution when calculating the covariance of returns. No adjustments need to be made to calculate covariance and downside risk in the shipping problem.

Minimum Acceptable Return

One concept which makes the CLPM model so versatile is the concept of an investor defined minimum acceptable return. In the case of a financial problem, it is relatively easy for an analyst or investor to define a goal return on which to base the allocation analysis. In the case of the shipping problem, however, it is much more difficult for a decision maker to justify a minimum acceptable return, whatever value he or she may choose. It is unrealistic to choose 100% as a minimum acceptable return, but nearly impossible to justify any number below 100% as a “goal” to achieve. For the case of the shipping route problem, the most appropriate value to use as a minimum

acceptable return is the current rate of return, which allows the model to provide only results which are as effective as the current routing mix or better.

Data Identification and Collection

Given the adaptations to the model described above, there are a number of relevant pieces of data which need to be acquired to implement the CLPM model for the shipping problem. The most obvious required figures are the daily percentages of cargo value arriving in Afghanistan over a defined period of time. In order to build those percentages, two distinct sets of data are necessary: the value of cargo arriving at the final destination and the value of cargo which left the port of origin.

Value at Port of Origin

The value of cargo at the point of origin is a key set of data for the shipping problem. It serves as the denominator for the calculation of percentage of cargo arriving, and serves as a baseline numerator value from which loss and damage are subtracted. This information was acquired from the Strategic Business Office of the US Army's Surface Deployment and Distribution Command (SDDC/G9) by way of packing lists for cargo going through Pakistan. Most US cargo which travels overland through Pakistan has an itemized packing list with declared values for cargo being carried. No similar system is currently in place for cargo traveling along the NDN. Using this historical data, the average value of shipments by class of supply along the PAKGLOC have been estimated and used as baseline cargo values for the purposes of analysis. Where historical data is not available, an industry standard estimate of $28,000 per TEU is substituted (Kirchner 2006:3).

Value at Final Destination

Often, some form of loss or damage occurs between the point of origin and final destination of a shipment. When this occurs, the receiving unit files a Standard Form 361, Transportation Discrepancy Report (TDR) which provides the details of the shipment, but most importantly provides an estimate of the value of loss or damage which occurred during shipping. This information provides the required data to build a final percentage of the value of shipped goods which reached the final destination. When the TDR value is subtracted from the original estimated value of the cargo and divided by the same, a simple percentage is found which represents the returns for the shipping problem.

Data Availability and Sufficiency

As previously noted, customs values for shipments along the NDN are not recorded, and therefore the values must be estimated through comparison of contents. While the calculations to obtain this information are fairly simple, the amount of data required to complete the calculation is quite large, and the required data is not in a consolidated database or other form. This situation makes the full value of shipments along the NDN very difficult to obtain. The complication of NDN data was compounded after the TDR values were received. Since the inception of the NDN, three total TDRs have been filed for shipments along the route. The lack of TDR data indicates either that there have only been three cases of loss or damage along the NDN, or that there have been situations where loss or damage has occurred and no TDR was filed. Since its inception, the levels of pilferage along the NDN are estimated to be between 0.5% and 1.0%, so it is clear that there have been a number of situations where loss occurred and

no report was filed. As exact data for pilferage along the NDN route is not available beyond overall percentages, more discrete data for pilferage was synthesized using theoretical distributions.

Data Synthesis

A number of steps were employed in order to ascertain a theoretical distribution of the percentage of cargo reaching its final destination along the NDN route. First, a distribution was created to describe the number of deliveries arriving on a given day via the NDN. The data used to build the distribution came from a record of deliveries to Afghanistan via the NDN as recorded in iSDDC from January through June of 2010, the most recent and consistent record of deliveries; 13,846 deliveries in total. Using the data fit function of the @RISK software produced by Palisade Decision Tools, the deliveries were found to be adequately described by an exponential distribution with a λ value of 80.929. The p value of the Chi-Square test for goodness of fit is 0.304, indicating a very good fit.

Following this data fit, some assumptions were required. First, it was assumed that for an incident to be defined as “pilferage” instead of an event which would cause a TDR to be filed, 10% or less of the cargo value could be taken. In the absence of further information, it was assumed that the amount of value remaining after pilferage, given that pilferage occurred, could be adequately described by a uniform distribution with a lower bound of 0.9 and an upper bound of 1. The final piece of required information to be used was the quoted levels of pilferage throughout 2008 of 0.5% and 1.0%. Using these estimates, the probability that a given delivery would experience pilferage was described

as a binomial distribution where *n*, the number of trials, equals the value found by the previously described exponential distribution; and *p*, the probability of a success, is equal to the estimated level of pilferage divided by the expected value of the percentage of value pilfered. This calculation is shown graphically in Figure **7** below.

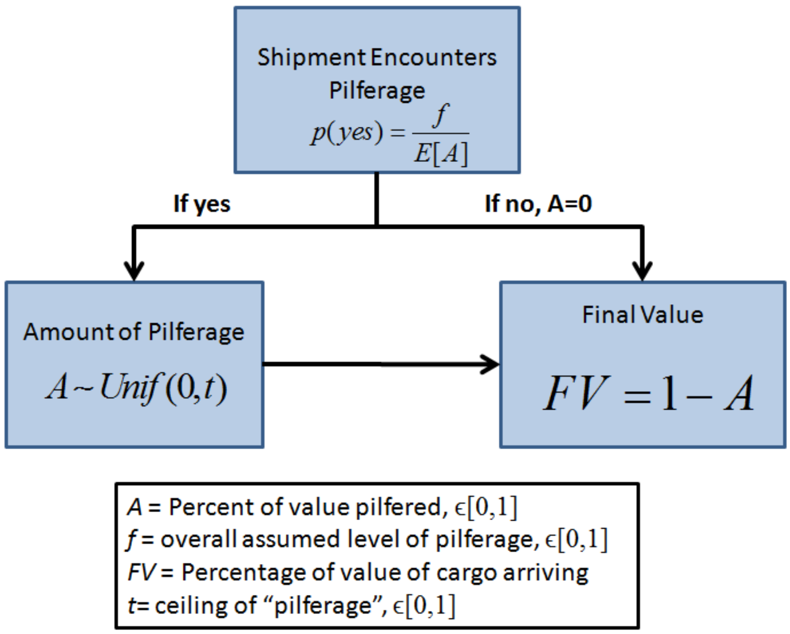


Figure 7. Flow of Calculations for Individual Shipment Pilferage Values

In summary, the number of deliveries was described using an exponential distribution, the number of those deliveries which experienced pilferage was described using a binomial distribution with the probability of success described in the paragraph above, and the value of cargo remaining after pilferage described using a uniform distribution. Using these distributions, a test case of daily values over a six month period was generated for overall pilferage levels of 0.25%, 0.5%, 0.75%, and 1.0%, and a distribution was fit for the final daily values of cargo reaching the final destination. The final distributions all fit logistic distributions with varying location and shape parameters.

The parameters for each level of pilferage are listed below in Table 2. Because the logistic distribution is not bounded, the final distributions are the minimum of the random draw and a value of 1.

Table 2. Logistic Distribution Parameters

Pilferage Level	Probability of Pilferage	Location Parameter	Shape Parameter	Chi-Squared P Value
0.25%	0.05	0.9978424	0.0011097	7.6×10^{-8}
0.5%	0.1	0.9952365	0.0018611	0.0019
0.75%	0.15	0.9930264	0.0020986	0.1260
1.0%	0.2	0.9903093	0.0027123	0.2398

Model Implementation

Through research and synthesis, the two sets of data required by the Sing and Ong CLPM model were gathered and formatted. With one year of data built for the PAKGLOC and NDN routes, it was possible to execute the CLPM model in its discrete form as defined in equation (2.16), and solve the optimization model given in equation (2.17). The data for the PAKGLOC was implemented in the model using data from June 2009 through June 2010. The data for the NDN was created using random sampling from the logistic distributions defined above. Using Microsoft Excel's built in random number generator, a random variable can be obtained using an inverse transform of the cumulative density function in the form of:

$$\min\left(-s*\ln\left(\frac{1}{r-1}\right)-l,1\right) \tag{3.1}$$

Where s and l are the shape and location parameters listed in Table 2 above, respectively; r refers to the result from the built-in random number generator for Microsoft Excel; and the minimum function bounds the distribution at 1 as its highest

value to eliminate the possibility of cargo gaining value along the route. A full year of returns was synthesized using this transform for comparison with historical PAKGLOC values.

Having recorded and synthesized the required data, the CLPM from equation (2.16) was then calculated for the current set of data. In addition, the expected return over the entire year was calculated using a simple weighted sum, and the Sortino Ratio calculated using equation (2.14). Finally, a simple measure of correlation was calculated for comparison with the CLPM values to depict the value of diversification.

Model Execution

The model was executed using a simple Visual Basic for Applications (VBA) code built by the author. The code generates a year of daily return data for the NDN route and solves the optimization problem in equation (2.17) using Microsoft Excel's built-in solver. After the minimum CLPM value is found while still achieving the minimum acceptable return, the code collects the percentage of cargo which should be sent down the PAKGLOC route, the CLPM value, the expected return, the Sortino Ratio, and the correlation for the data set used. The code runs for 500 iterations for each level of pilferage and outputs the results on a separate worksheet for each case. The model runs all four cases in about 6.5 minutes on a 2.2GHz PC.

IV. Analysis

Discrete Analysis

As a starting point for data analysis, a better picture of the asset allocation problem was found using a set of discrete values for the percentage of cargo sent along each path. Each set of discrete values represents a scenario where X% of the cargo travels along the PAKGLOC Route and Y% of the cargo travels along the NDN route, and X and Y sum to 100%. By finding risk and return values for each of these sets of values, a graphical representation of the allocation problem was found. The first graphical representation of interest is a graph of the risk and return values for each set of values. The graph for a sample case can be found in Figure **8**.

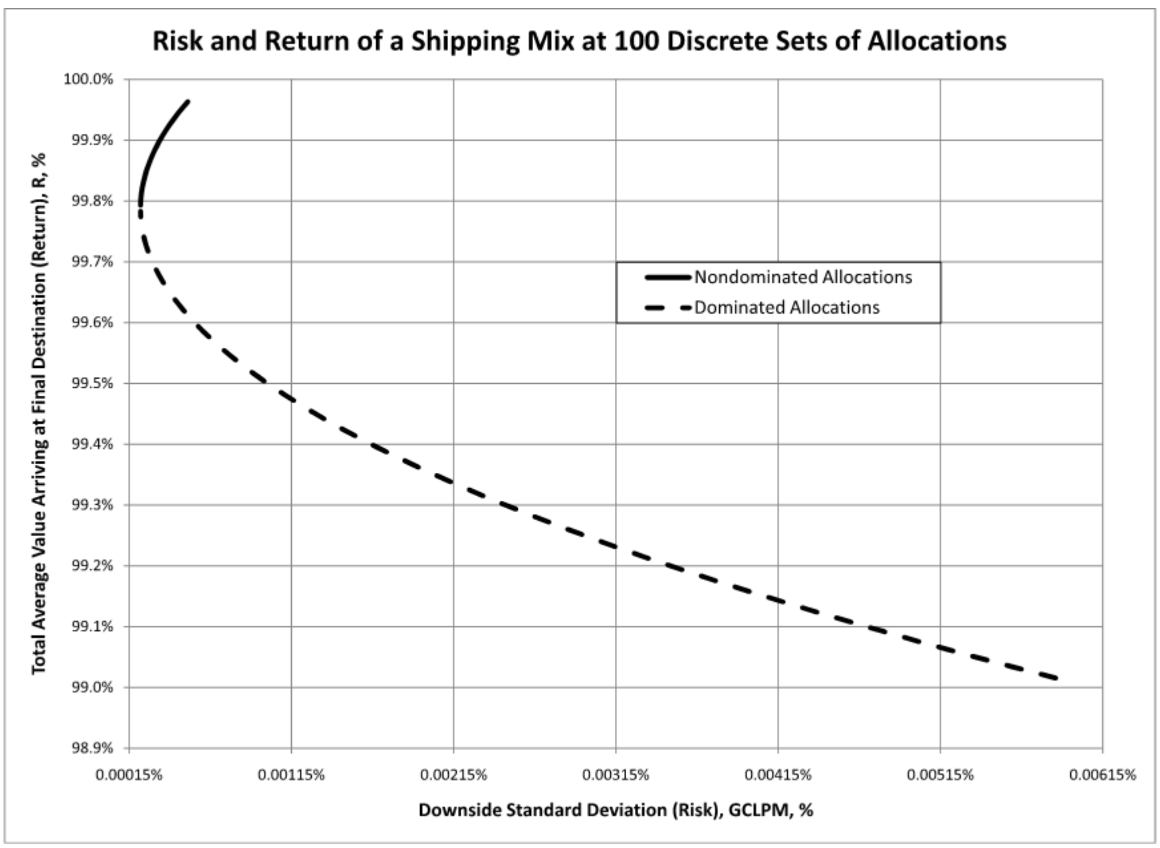


Figure 8. Risk and Return of a Shipping Mix at 200 Discrete Sets of Allocations

It can be seen from the graph that there are two general trends in the graph. First, there are a set of values for which the risk decreases as the return increases, indicated by the dashed line. These are both preferable tendencies, meaning these particular points are dominated. The second set of values, indicated by the solid line, show that for an increase in return one must also increase risk, making a tradeoff of one preferable characteristic for another. These points are nondominated and make up the efficient frontier of shipping allocations. Essentially, any of the nondominated points may be selected by an investor and considered to be efficient, although none is truly optimal. The way the Sing and Ong model is used, it is assumed that we would like to minimize risk as long as the return is above a defined minimum acceptable return. In the specific case shown in Figure **8**, the minimum acceptable return is about 99.6% so all of the nondominated points are feasible given this constraint. Given this situation, the optimal mix is the nondominated solution with the lowest risk having a return of about 99.8% in this case.

A second representation of the data uses the previously defined Sortino Ratio. Using the same discrete set of values, the Sortino Ratio value is plotted against the percentage of cargo to be sent along the PAKGLOC path to ascertain another view of the optimal solution in Figure **9**.

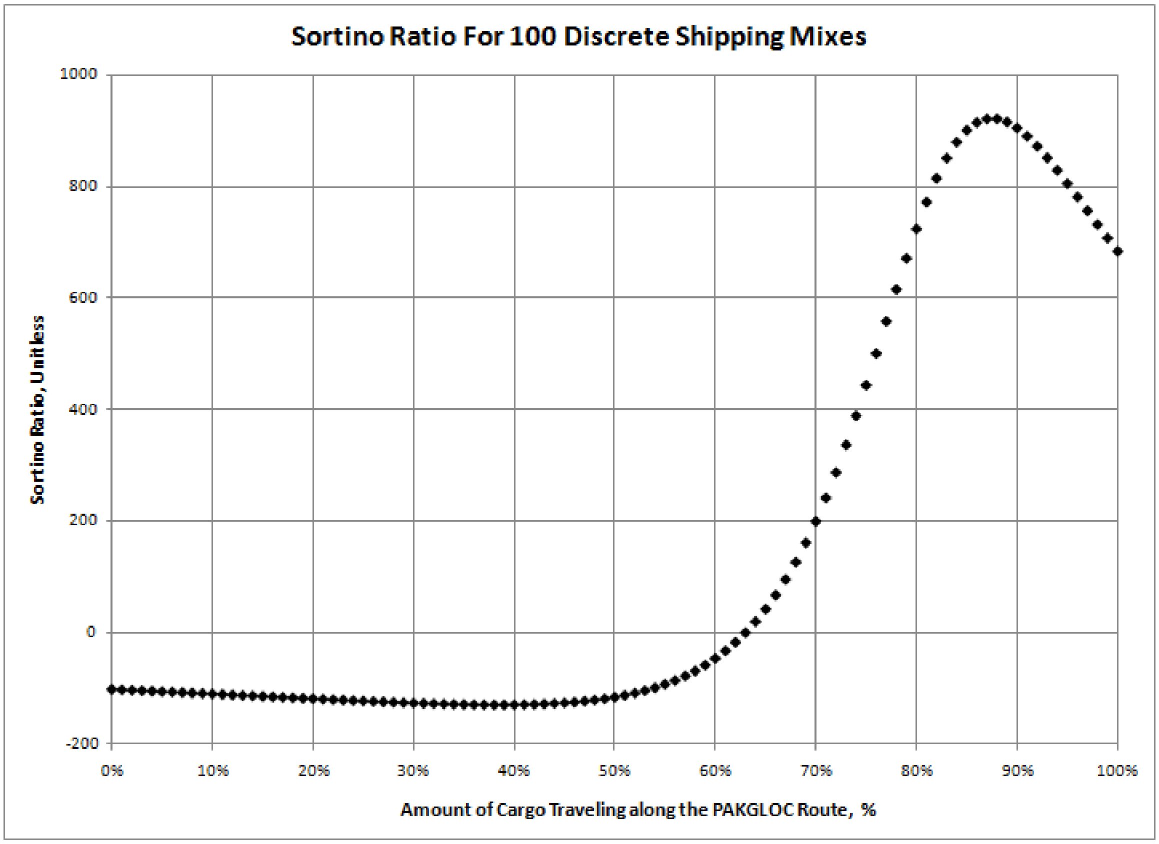


Figure 9. Sortino Ratio for 100 Discrete Shipping Mixes

In the graph above, the Sortino Ratio indicates an optimal solution at its global maximum. Sortino Ratio values which are less than zero indicate a shipping mix for which the return is less than the minimum acceptable return. In this case, it is easy to see by the Sortino Ratio that the optimal mix occurs when about 88% of the cargo is shipped via the PAKGLOC. These two discretized representations of the data give a clear graphical representation of the problem, and assist in finding the optimal value for a given scenario. In the scenario used above, the optimal percentage of cargo to send along the PAKGLOC is 83.4% via the Sing and Ong model and about 88% via the Sortino

Ratio. For the shipping problem at hand, optimal values are found using the Sing and Ong model, a more rigorous model, while Sortino Ratios are presented for reference.

Model Results

The model described in Chapter 3 was run for 500 iterations at each of the four given levels of pilferage and the optimal solutions found. Following the gathering of the results, the mean and standard deviation of the percentage of cargo traveling along the PAKGLOC route were calculated to show the spread of possible results given different input data. The mean and standard deviation for each scenario are given in Table 3.

Table 3. PAKGLOC Percentages for Varying NDN Pilferage Levels

NDN Pilferage Level	Average PAKGLOC %	Standard Deviation
0.25%	61.4%	0.0185
0.5%	68.7%	0.0376
0.75%	74.2%	0.0450
1.0%	80.2%	0.0347

In general, the trend of the PAKGLOC percentages is as one would expect; as the pilferage along the NDN gets worse, more cargo should be shipped along the PAKGLOC route. Given that the PAKGLOC percentages within each pilferage level follow a generally bell-shaped curve, a spread of possible solutions was found using the guide that 95% of returns will fall within 2 standard deviations on either side of the mean for a normal distribution. Figure 10 shows the intervals in which one can expect about 95% of the PAKGLOC shipping percentage results to fall for a given set of past returns.

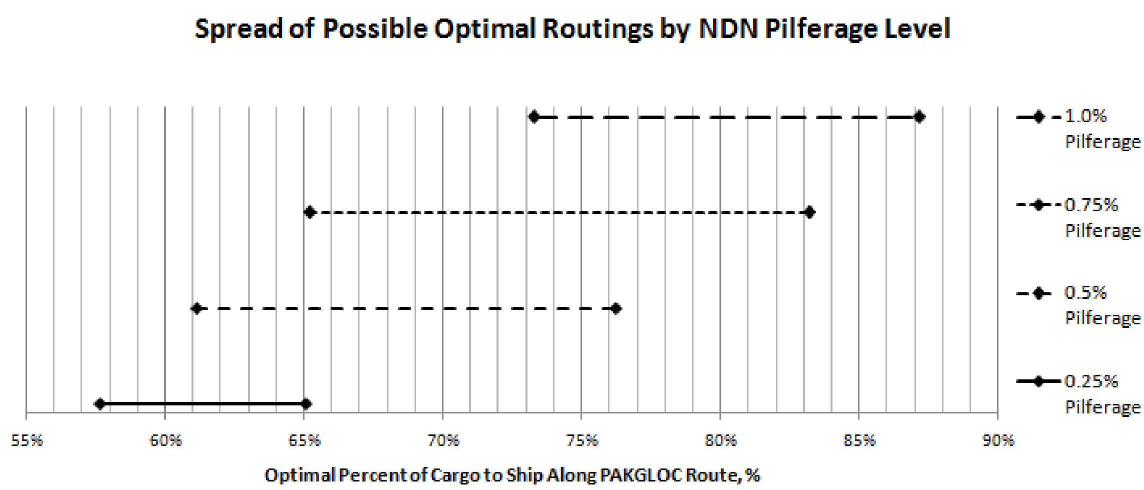


Figure 10. Spread of Possible Optimal Routings by NDN Pilferage Level

It can be seen fairly easily in Figure 10 that possible optimal values depend upon the historical data used in the model. Because the data used in the current model was made largely of random distributions, the spread of possible optimal values is quite large. In even the tightest range, there is more than a five percent range in which the optimal value could lie given the information available.

An Alternate Look: Sortino Ratio

To gain further insight into the results, the model was then made to maximize the Sortino Ratio for each scenario over 500 iterations. The Sortino Ratio does not seek to minimize risk, but instead is a method of finding the best tradeoff between expected return and risk. While the minimum risk scenario will generally provide an expected return close to the minimum acceptable return, the Sortino Ratio will attempt to “buy” the user a better expected return rate at the cost of the level of risk until the Ratio reaches a

maximum point as shown in Figure **9**. The results of the model are shown in Table 4 below.

Table 4. Average PAKGLOC Percentages for Minimum Risk and Sortino Ratio Methods

NDN Pilferage Level	Minimum Risk Result	Sortino Ratio Result
0.25%	61.4%	62.35%
0.5%	68.7%	76.34%
0.75%	74.2%	87.04%
1.0%	80.2%	86.60%

While the results of both methods are comparable, it is clear that the Sortino Ratio results are consistently higher than the minimum risk results. As the pilferage level along the NDN increases, the expected return obviously decreases. In order to improve the expected return, the Sortino Ratio is forced to increase the amount of cargo traveling along the PAKGLOC at the cost of a small amount of risk. When the Sortino Ratio results are plotted with the same two standard deviation spread as the minimum risk results above, Figure 11 is produced.

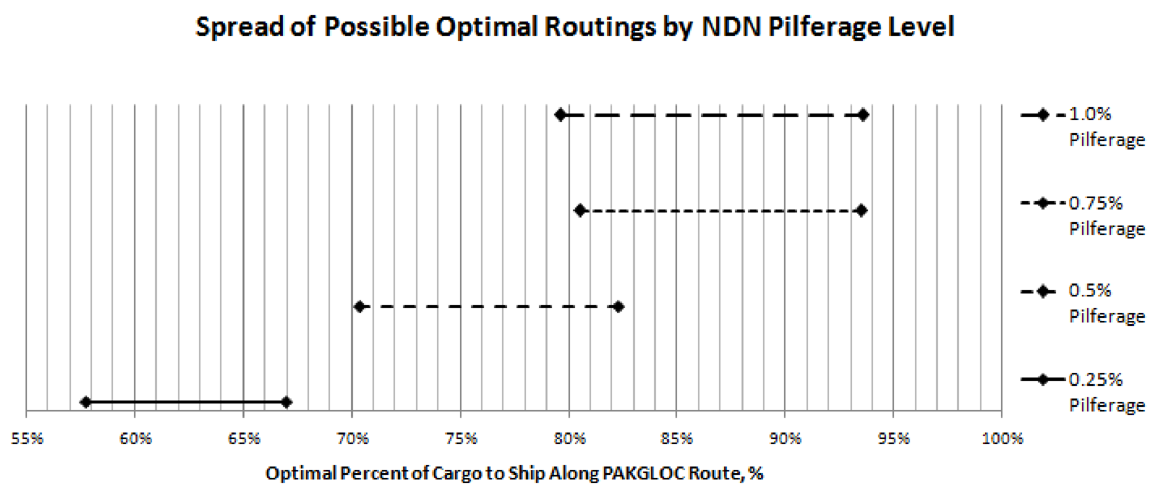


Figure 11. Spread of Possible Optimal Routings by NDN Pilferage Level - Sortino Ratio Method

While the results of the Sortino Method analysis show significantly less overlap between pilferage levels, the spread of possible optimal results within each pilferage level is still large enough to require more precise data and assumptions before being able to pinpoint a range in which to operate.

Examining the Spread: Correlation Between Paths

Given the static nature of the returns for the PAKGLOC route, and the relatively constant rate of return for the NDN route, there is clearly another factor at work causing the spread of possible optimal values shown above. When the asset allocation problem was viewed at its simplest by Dr. Markowitz, he identified three critical components to the problem: return of the investment, variance of the returns, and the covariance between the returns of the assets. Throughout the evolution of the asset allocation problem, these three factors have remained, in some form, the nucleus of the problem.

As returns and the variance of the returns in the presented case are fairly consistent, the only remaining factor is the covariance or correlation between the returns of the assets.

Correlation between the returns, in general, has a negative effect on the overall risk of the portfolio. If, for example, there is one day where no cargo at all arrives safely through the PAKGLOC route, it clearly raises the risk associated with that route. If, however, no cargo arrives safely through the NDN route on the same day, it cannot be assumed that one route has more risk than the other. If the correlation between the returns is high, any increase or decrease in returns which exists along both routes is attributed to a change in the system rather than the risk of one route or the other. Given this relationship, an examination of the correlation between return streams is certainly in order.

As the simulation is run, a simple measure of correlation between the two routes is collected and recorded for each iteration. Following the completion of the runs, another correlation measure is introduced, measuring the correlation between the risk value and correlation value for each run. Using this measure, it is possible to see what level of interaction exists between the risk for a given simulation and the correlation of returns for that same simulation. The correlation coefficients described above were found for each of the four pilferage scenarios, and the risk and correlation figures for each iteration graphed to find any interaction which may exist between the two. The results are displayed in Figure 12 through Figure 15.

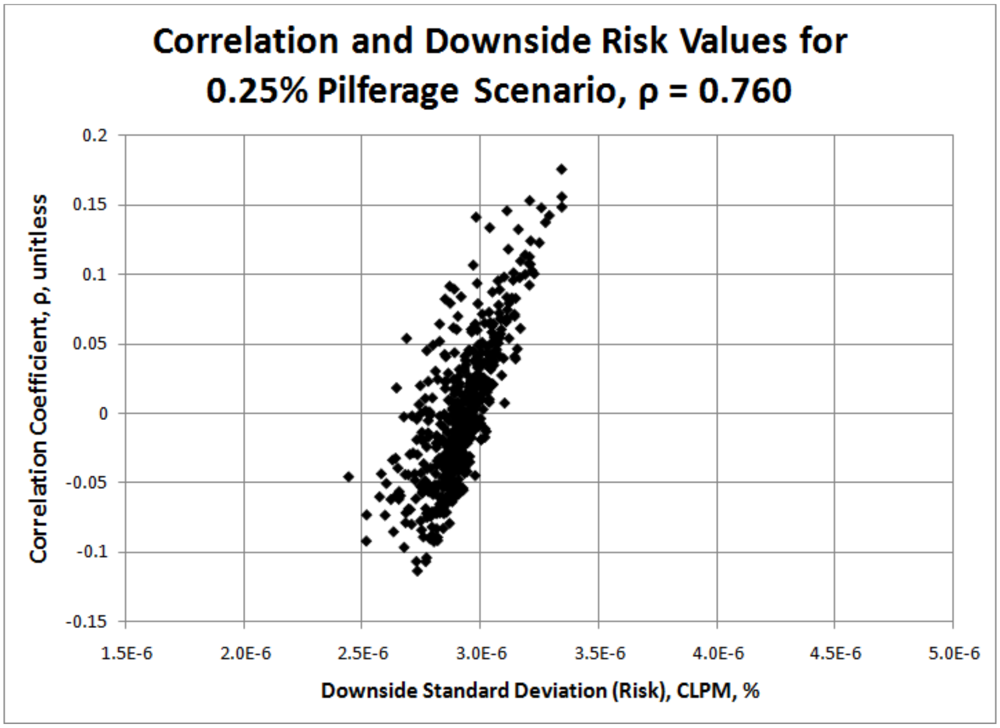


Figure 12. Correlation and Downside Risk Values for 0.25% Pilferage Scenario

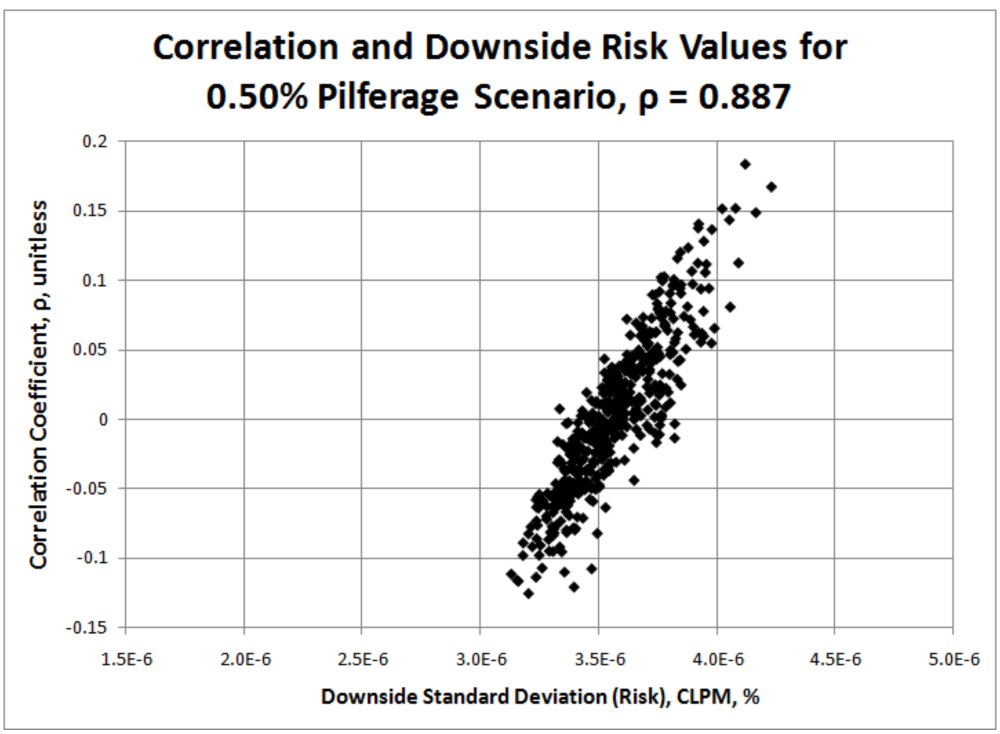


Figure 13. Correlation and Downside Risk Values for 0.5% Pilferage Scenario

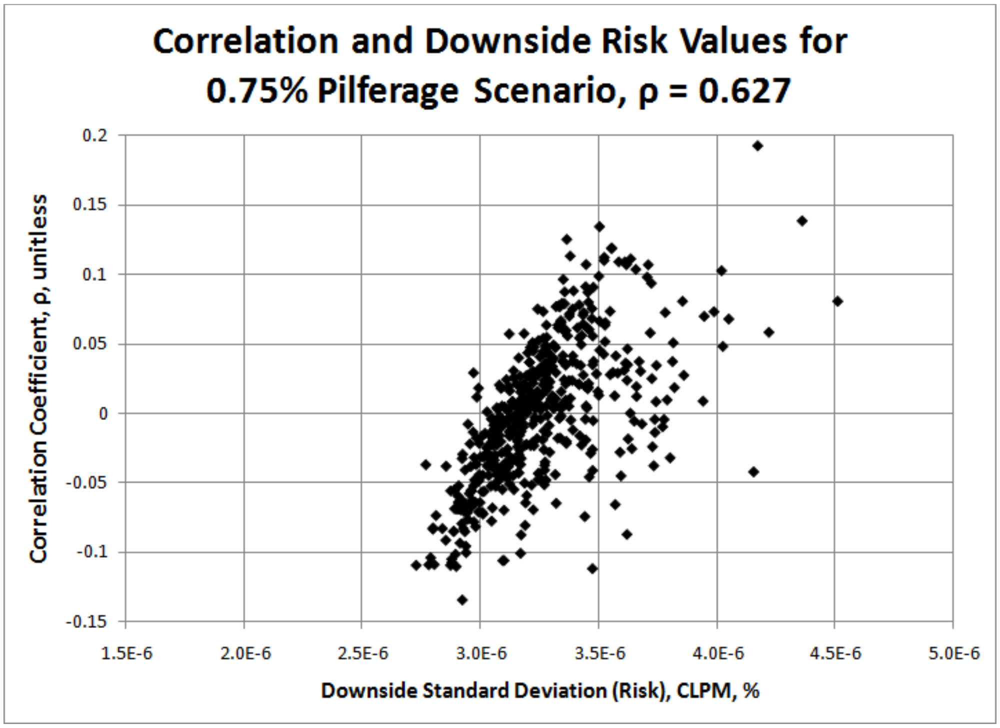


Figure 14. Correlation and Downside Risk Values for 0.75% Pilferage Scenario

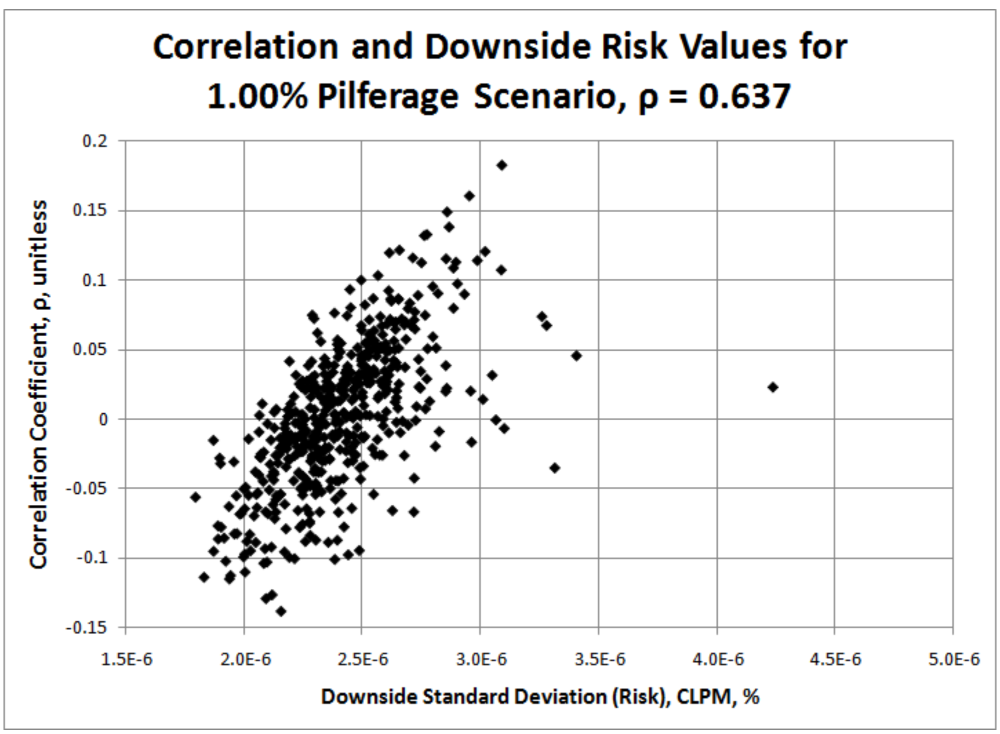


Figure 15. Correlation and Downside Risk Values for 1.00% Pilferage Scenario

It can be clearly seen from both the general trends in the above graphs and the final correlation values as annotated in the title of each that there is a high degree of correlation between the overall risk of a shipping mix and the degree of correlation between the assets in that mix. In simpler terms, as correlation between assets increases, overall risk decreases.

Cost Considerations

Most asset allocation problems do not take into consideration the cost of the assets to be bought or used because most problems involve stocks and other financial assets. In essence, they assume that an investor has a set amount of money to invest and is attempting to find out what percentage to invest in each. In the logistical case, however, we are moving a set amount of cargo and attempting to find what percentage of cargo to send down each path. There is, however, some cost associated with shipping down each path, and that cost is certainly not equal between the two. As mentioned in Chapter 1, the cost of shipping down the NDN is roughly three times as high as shipping down the PAKGLOC route. The average cost of a shipment along the PAKGLOC is about $9,789, while the average cost of a shipment along the NDN is about $20,123 (iSDDC).

There are a number of ways to factor cost into the analysis of the shipping mix problem, but there are also a few drawbacks. Most simply, one could introduce a constraint which states that the shipping cost of the final portfolio must be less than the current shipping cost. If this constraint is introduced, however, it forces the percentage of

cargo traveling along the NDN to be less than 37%. One can assume, however, that a constraint which stifles diversification in such a way would not be preferable in this type of problem.

A second consideration may be that the reduced risk would have a lowering effect on the shipping cost, possibly allowing more travel along the NDN than one might expect. As can be seen from the above results, however, the systems we are considering have a considerably high average return (generally above 99%), and therefore very low risk values. The downside standard deviation at its highest observed value, for example, is about $4.5\text{x}10^{-6}$. Again assuming a fairly bell-shaped curve, we can multiply this figure by three to find out how much could be protected given a 99% worst case scenario, the result being $1.35\text{x}10^{-5}$. Multiplying this final value by $4.9 billion, the total estimated value of cargo traveling over the course of a year, yields the highest possible value protected or saved of $66,150. While this number is a rough estimate, it tells us that with the lowered risk, we could afford to ship a total of six more shipments down the NDN, a 0.02% increase from the current levels.

In three of the four cases, however, the levels of NDN shipment recommended is lower than the current levels resulting in a cost decrease from the estimated $1.681B in 2009 shipping costs along with a decrease in risk. The final estimated transportation values and savings based upon average shipment cost and optimal percentage are shown in Table 5.

Table 5. Annual Shipping Savings for Average Solution for Each Scenario

NDN Pilferage Level	Total Shipping Cost	Total Shipping Savings
0.25%	$ 1,701,581,196.90	$ (20,419,786.40)
0.5%	$ 1,608,415,921.45	$ 72,745,489.05
0.75%	$ 1,538,222,905.70	$ 142,938,504.80
1.00%	$ 1,461,648,706.70	$ 219,512,703.80

These values show that if the pilferage level along the NDN is around 0.5% or above, not only can the risk be decreased for the total shipping mix, but the cost of shipping those materials can be reduced as well. Unfortunately, however, there is not enough of a savings from the decrease in risk to make a significant difference in the overall cost of shipping.

V. Conclusion

Research Overview

The purpose of this research was to determine the correct percentage of cargo flowing into Afghanistan to ship via the PAKGLOC and via the NDN. To this end, a financial model known as Post-Modern Portfolio Theory (PMPT) was adjusted and applied to the problem to determine the appropriate shipping mix. About two thirds of the cargo flowing into Afghanistan travels via the PAKGLOC, while only about one third travels via the newer NDN. Concerns of loss and damage along the routes called for an analysis of the risk along each route, and an overall shipping mix to minimize the total risk. Using the concept of stock diversification in a shipping context, the correlation of return streams for each route was exploited to reduce total risk.

Building upon the work of Nobel Laureate Harry Markowitz, economists such as Harlow, Rao, Sharpe, Sortino, Sing, and Ong collectively developed a method of determining an optimal asset allocation based upon the concepts of return, downside risk, and correlation. Optimal asset allocation began using simply the mean, variance, and correlation of various return streams. Along with minimizing risk, metrics were developed to use the overall risk and return of the portfolio to provide an alternate optimal solution. As computing power increased over time, the use of variance to measure risk was replaced with the concepts of semivariance and the lower partial moment to identify only those returns below the mean. Continual improvements led to the use of a minimum acceptable return for a portfolio rather than simply the mean, and

finally to a discrete version of the lower partial moment concept such that downside risk could be analyzed through a simple spreadsheet.

The PMPT concept was to better fit a logistics and shipping context using the percent of cargo value reaching its final destination to form returns. Using information gained from Transportation Discrepancy Reports filed through SDDC as well as various measures of the total value of a twenty foot equivalent unit, these percentages were built for shipments along the PAKGLOC. Along the NDN, given a lack of available data for both loss and damage as well as cargo value, returns were synthesized using estimates of possible pilferage levels along the route along with binomial and uniform distributions to create representative returns. Using the concept of downside risk as defined in an optimization model from a 2000 article by Sing and Ong, an optimal mix of the two routes was identified for a given set of returns. Returns were created for nominal NDN pilferage levels of 0.25%, 0.5%, 0.75%, and 1.0% and analyzed using a simple Monte Carlo simulation. Five hundred sets of returns were synthesized for each scenario and analyzed to find the optimal shipping mix, the associated risk and return, and the cost of using that particular shipping mix.

An analysis of the results of the Monte Carlo simulation showed that although the mean and variance of the returns along the NDN route remained constant, the optimal percentages of cargo to send down each route varied greatly. Further analysis showed that the correlation of the returns for the routes at each iteration was a large factor affecting the risk level and final mix. Overall the final percentages could vary by as much as 10% or more on either side of the mean. Cost considerations added further complication due to shipments along the NDN costing three to four times as much as

similar shipments along the PAKGLOC. This fact means that any increase in shipment down the NDN would cause a complimentary increase in cost, capping the use of the NDN at current levels. Although shipping more cargo along the NDN might decrease risk, the decrease is at such a small level that it would have a negligible effect on overall shipping cost.

Strengths and Limitations

The model used in this research has been well tested and thoroughly developed for economic and financial research since the 1950s, which speaks volumes to the validity of the model. The shipping mix problem was easily transformed to fit the PMPT model, allowing for its almost direct application and ensuring that its basic concepts held true. Also, the PMPT model was easily implementable through a spreadsheet, and the analysis was done quickly and simply due to the relative simplicity of the concepts involved.

While the PMPT model can provide valuable insights into the shipping mix problem, it requires the most accurate data possible regarding past shipments. This research has shown that although returns can be synthesized through theoretical distributions, the final results can vary greatly due to the lack of time-correlated data. In addition, this research shows that the risk decrease that can be achieved using a different shipping mix may be rather small when compared to the required cost increase.

Conclusions and Recommendations

This research has shown that Post-Modern Portfolio Theory can be quickly and accurately used to analyze the appropriate mix of assets in any number of arenas including the shipping business. This research has applications internationally as shown through the PAKGLOC and NDN case, but also domestically on a smaller scale to reduce risk associated with different shipping routes. Unfortunately, although a great amount of insight can be gained through this research, it is only as good as the data behind it. To better the analysis done here, we recommend that USTRANSCOM stress the importance of the timeliness and accuracy of the Transportation Discrepancy Report system to ensure that any and all loss and damage is captured and reported. It is anecdotally suggested that only about 60% of loss and damage is reported as filing the report does virtually nothing for the unit awaiting the cargo. In addition, USTRANSCOM should look into methods of estimating the value of cargo being shipped into Afghanistan. Currently, only a small number of shipments have the value of their cargo recorded which makes it difficult to measure the percentage of cargo which is lost or damaged. The more consistent and reliable these two pieces of data are made, the easier it will be to pinpoint the optimal shipping mix to minimize risk.

The results of this research show that there is a vast array of shipping mixes which could reduce risk in shipping. There are almost certainly other factors involved in shipping cargo into Afghanistan which could help narrow down the best choices. While this research should not be used alone to determine the best shipping mix, it certainly provides valuable insight into a part of the problem. Through the use of this research and

the consideration of other factors, risk in international shipping can be dramatically reduced.

Appendix A: Blue Dart

DIVERSIFICATION ISN'T JUST FOR YOUR STOCK PORTFOLIO

Investors have told us for decades to diversify our investments to keep our money safe. We all understand the general concept of diversification, but rarely do we think about the mechanics behind the scenes. How can I actually decrease the risk I'm taking on in my portfolio by investing in varied stocks? A recent master's thesis from the Air Force Institute of Technology explores the behind-the-scenes math that keeps our investments safe, then applies the diversification concept to an arena far from its financial roots: Shipping supply into Afghanistan.

In essence, diversification was first quantified in 1952 by Dr. Harry Markowitz who created a series of equations designed to help the investor decide how much of their money they should invest in a number of stocks. Dr. Markowitz recognized that investors generally want to keep their return high and their risk low, but within a single stock these concepts are often inversely related. Given this relationship, Dr. Markowitz associated the variance of returns of a stock over time with the overall risk of the stock. To calculate the risk of the overall portfolio, Dr. Markowitz used a simple covariance measure to determine how similar the return trends had been for each stock. If the returns had very similar trends, then investing in both did not necessarily qualify as diversification, and the risk reduction was minimal. If the returns had very different trends, however, the low covariance would lead to a lower measure of overall portfolio risk.

The major drawback to Dr. Markowitz's work was that it considered returns above the average to be just as risky as returns below the average. Over time investment mathematicians revised the formulas, resulting in a more complicated but more intuitive measure of risk for a given portfolio. At the same time, other investment mathematicians concentrated on finding the best portfolio from a set of efficient portfolios. The result was a measure still used today which simply takes desired measures and divides them by undesired measures, much like a thrust to weight ratio, or even "bang for your buck". By dividing the expected return by the calculated risk, a single portfolio could be found which is the "best" option for the investor.

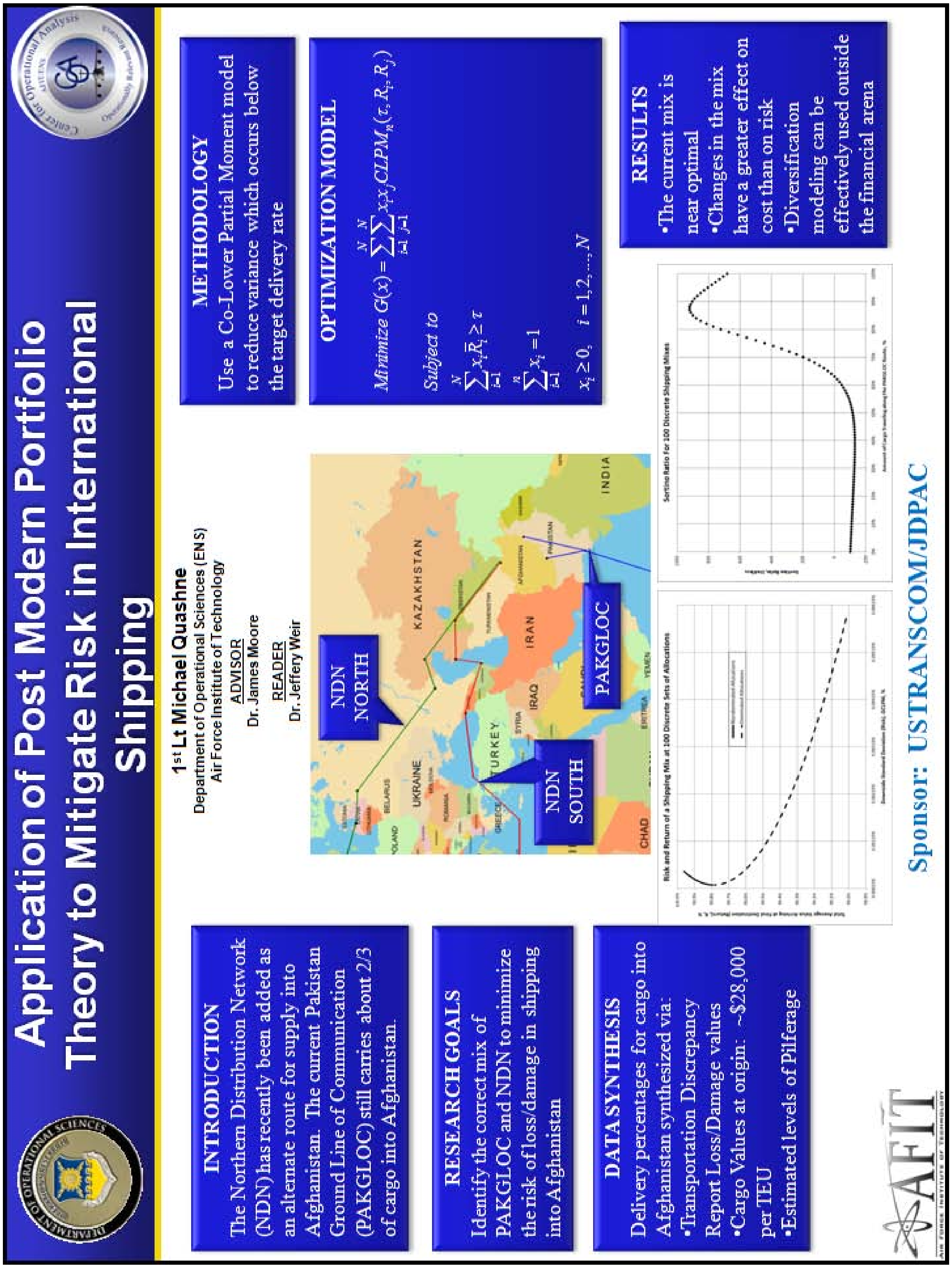
While this concept is well known in the financial arena, there has been little research into applying the diversification concept in other areas. In the winter of 2010, AFIT student 1st Lt Michael Quashne took on a project from USTRANSCOM asking him to do just that. USTRANSCOM was trying to find out how much cargo they should send through the Pakistan Ground Line of Communication (PAKGLOC) and how much to send through the Northern Distribution Network (NDN) to minimize the risk of loss or damage along the way.

About $5 Billion in assets are shipped into Afghanistan every year, so protecting those assets is a crucial part of the process. Using historical information on loss and damage, the research follows Markowitz's steps as revised by others to examine the effect of diversifying between the two routes to minimize risk. The research finds optimal shipping mixes for a number of scenarios as well as the cost effects of each mix. Throughout the course of the research, it becomes clear that the equations used for diversification can be used in any number of areas outside of the financial paradigm.

Imagine, for example, a football quarterback with two star wide receivers. Receiver number one is a deep threat, he is known for catching deep passes, but may only catch a few during the course of a game. Receiver number two, however, is a possession receiver; he can usually be counted on to receive a large number of passes, but only for short yardage. Coaches could use historical measures of performance to find out how much of the time the quarterback should throw to each receiver to maximize yardage gained, while minimizing games where actual yardage falls below the target.

Diversification is a powerful concept that as of yet has been relegated to its financial world and hasn't seen much exposure. It is a concept, however, which has applications far beyond the financial, allowing the Air Force to optimize processes to ensure consistent success.

Appendix B. Summary Chart



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Vita

Lieutenant Quashne is a 2007 graduate of the United States Air Force Academy with a Bachelor of Science degree in Aeronautical Engineering. His first assignment was as a Study Skills instructor at the Air Force Academy before entering the Joint Specialized Undergraduate Training Program as a student at Vance Air Force Base, Oklahoma. Following a medical disqualification, Lieutenant Quashne was reassigned to the Force Support Officer career field and moved to Wright-Patterson Air Force Base, Ohio. He served as the Squadron Section Commander for the 88th Mission Support Squadron before entering AFIT in August of 2009.

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14. ABSTRACT
This research uses asset allocation concepts to determine the correct amount of cargo to send down the PAKGLOC and NDN to minimize the risk of loss or damage. Loss and Damage data is used from Transportation Discrepancy Reports and overall value is assumed to match the industry standard. Using assumed levels of pilferage along the NDN, a Monte Carlo simulation is run at each level of pilferage, and a Co-Lower Partial Moment model is solved. Analysis of the data shows a wide spread of possible optimal solutions at each level of pilferage. Due to the low levels of risk along each route, risk is not an appropriate factor to use alone to determine the best shipping mix into Afghanistan.

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